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Applying Project Based Learning In An Undergraduate Design And Construction Program At Appalachian State University

By: **James A. Russell, PhD, Chelsea R. Helms**, R. Chadwick Everhart, EdD, & **D. Jason Miller**

Abstract

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APPLYING PROJECT BASED LEARNING IN AN UNDERGRADUATE DESIGN AND CONSTRUCTION PROGRAM AT APPALACHIAN STATE UNIVERSITY

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INTRODUCTION

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KEYWORDS

project based learning, curriculum reform, integrated design, design-build

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INTRODUCTION TO PROJECT BASED LEARNING

Project based learning, or PBL, is a term commonly used to describe an active learning pedagogical approach and can be roughly associated with other active learning terms including, but not limited to, discovery learning, problem based learning, experiential learning, and inquiry-based learning. Active learning is best defined as any educational paradigm that encourages and facilitates student ownership of their learning (Nieweg et al, 2005). Active learning approaches trace their roots to constructivist learning theory as established by notable educator and researcher, John Dewey, during the early decades of the twentieth century. Dewey's learning theories were an initial response to numerous societal and cultural shifts, transforming education from a classical approach of learning to an embrace of modernism. Rooted in rationalism, truth was no longer to be discovered, but constructed by the individual learner (Mooney, 2000). Constructivist theory was continued and expanded by other notable educators, including Maria Montessori, Lev Vygotskty, and Jean Piaget (Dewey, 1974; Ültanır, 2012).

Numerous learning approaches, such as discovery learning, inquiry teaching, peer-assisted learning and reflective teaching are a result of Constructivist theories and emphasize human cognition in education. When considering cognition in regards to learning, numerous key processes can be identified. One essential cognitive learning process that informed PBL was problem solving. According to Schunk, "Problem solving refers to people's efforts to achieve a goal for which they do not have an automatic solution" (2012, p. 299). Problem solving requires critical thinking from learners and is expressed through some form of strategy. Some common strategies employed in learning contexts include generate-and-test, means-ends analysis, analogical reasoning and brainstorming, all of which may be found in PBL (Schunk, 2012).

The PBL method moved from its elementary education roots into higher education first in medical schools in the form of case studies during the early 1970's and more recently in engineering schools in the form of capstone design courses (Barrows, 1986; Dutson et al, 1997). PBL has also been introduced into universities by innovative faculty members to allow students to take ownership of their learning experiences, think more critically and apply learning to real-world situations. According to Ken Bain's notable research into effective college educators, the best university instructors "try to create what we have come to call a 'natural critical learning environment.' In that environment, people learn by confronting intriguing, beautiful, or important problems, authentic tasks that will challenge them to grapple with ideas, rethink their assumptions, and examine their mental modes of reality" (Bain, 2004, p.18).

Project based learning is a student-centered method of teaching that intends to engage students in the solution of an authentic problem (Blumenfeld et al, 1991). Proponents of PBL contend that the method enhances student learning outcomes because: students are more motivated to focus and learn the material if they engage in solving an authentic problem; students participating in PBL are more likely to retain and internalize knowledge; and PBL allows students to relate their theoretical knowledge to the real world in essence allowing them to synthesize a unified view of their field of study from the fragmented content gained through various and disparate lectures and courses (Blumenfeld et al, 1991; Tasci, 2015; Wu and Hyatt, 2016). Opponents of project-based learning—and similar active learning techniques—object to the teaching method primarily because it requires that the teacher not give students a solution but rather coach them towards answers or solutions that the students must develop on their own. Opponents refer to this aspect of PBL as providing minimal guidance during instruction (Kirschner et al, 2006).

A REVIEW OF PROJECT BASED LEARNING ACTIVITIES IN THE BUILDING SCIENCE PROGRAM AT APPALACHIAN STATE

Architectural Design Studios: A First Step in PBL

In the fall semester of 2006, a new concentration in Architectural Technology and Design was established within the undergraduate Building Science program at Appalachian State University to complement the pre-existing concentration in Construction Management. Student demand existed for a formal architectural emphasis of study alongside a desire for more courses devoted to project-based learning. Up to this time, the program had historically included two design courses, one residential and one commercial, in an effort to strengthen communication between construction industry professionals and provide opportunities for creative problem solving for future construction managers. Because these courses proved to be the most popular in the program—which can be attributed to their focus on project-based learning—the faculty decided to expand course offerings with PBL emphasis into the new concentration via additional design studios.

Over the last twelve years, the four architectural design studios—one each semester for the final two years of study—have engaged in a plethora of project-based learning exercises. From one-room projects to comprehensive campus planning endeavors, PBL has launched a new wave of creative inquiry and tangible expression of ideas for students in the undergraduate Building Science program.

Most of the projects within the architectural studios have been completed for external clients, rather than focusing on experimental or hypothetical design problems. To engage students in service learning as well as promote a more real-world experience, faculty used these projects to equip students for future employment. Although these design-only projects did not include cost estimates and construction documents, the process of experiencing a real-world project captured the students' attention and helped "connect the dots" between many of the disparate elements of their coursework. As of the spring semester of 2017, students in these architectural design studios have completed dozens of design-only service learning projects with a variety of entrepreneurial, non-profit and governmental clients.

Design/Build: The Next Step in the PBL Experience

With the growing success of the Architectural Technology and Design concentration and the numerous design-only service-learning projects completed, the faculty ventured into a more complex form of PBL: design/build. In the fall semester of 2009, an architectural professor and sixteen senior design students inaugurated the design/build trajectory of Appalachian State. Within a single semester, the students worked with a non-profit organization to design and build a solar-powered mobile performance stage used to host concert events at a local park.

Although there were many challenges with this new form of PBL, the student learning that resulted from the experience encouraged the Building Science faculty to continue with design/build projects as a part of the student experience. Up to this point, however, design/build and much of the real-world projects had been limited to the Architectural Technology and Design studios. Many engineering-based and construction management faculty became optimistic about these PBL experiences, especially design/build. The hope was for all students in Building Science—both architectural and construction management—to have this unique experience before graduation.

The Solar Decathlon: PBL, Interdisciplinarity, and Competition

An opportunity for a more integrative learning experience across multiple programs in Appalachian State's College of Fine and Applied Arts—such as, Sustainable Technology, Interior Design, Industrial Design—emerged when Appalachian was accepted as one of twenty teams to participate in the 2011 Department of Energy Solar Decathlon (see Figure 1). The two-year design/build, net-zero energy residential project was directed by three Building Science faculty and led by a core group of twenty undergraduate and graduate students. Over two hundred students and multiple consulting professors from across the university participated in the project in some capacity. By the fall semester of 2011, the Appalachian State team had designed, built, tested, disassembled, transported, and reassembled its project, known as The Solar Homestead, onto the National Mall in Washington, DC, for the Solar Decathlon competition. The interdisciplinary team won the coveted People's Choice Award, while earning first place in the Solar Hot Water competition, second place in the Communications competition, and third place in both the Architecture and Home Entertainment competitions.

Building upon the success and momentum of its first Solar Decathlon project, Appalachian State chose to compete again, this time in the 2014 Solar Decathlon Europe (see Figure 2). This design/build project presented new design, construction, and logistical challenges to deal with the complexity of international standards and transatlantic travel. An expanded interdisciplinary team was developed around a core of Building Science faculty and students. Students and faculty from other departments, including Art, Business, Communication, Industrial Design, Music, and Physics, among others, contributed significantly to the creation of the energy-plus, passive house standard rowhouse prototype called Maison Reciprocity. The two-year project

FIGURE 1. Appalachian State University's Entry into the U.S. Department of Energy's 2011 Solar Decathlon, The Solar Homestead.

was another success for the university, the Department of Sustainable Technology and the Built Environment, and the Building Science program. Competing against an international field culled from sixteen countries and four continents, Appalachian State garnered first place in the Energy Balance competition, third place in a special Social Housing competition, and ninth place overall among the twenty finalists.

While these competitions provided significant student learning and real-world experience, they were considered special projects and yielded few student credit hours. The credit hours achieved by students were often electives and not an essential part of an undergraduate program of study. Considering the substantial time investment and overall commitment required, it seemed as if these projects demanded much from undergraduate students without helping a reasonable four-year path to graduation.

The Solar Decathlon projects also presented other difficulties for a design and construction program at a medium-sized regional comprehensive university. They were, and remain, very expensive endeavors, requiring substantial financial, faculty, and administrative efforts. Although the Department of Energy provided some grant funds to help begin the projects, significant fundraising was required to execute these projects to their full extent. While these projects brought international accolades to the Building Science program and the university at

FIGURE 2. Appalachian State University's Entry into the 2014 Solar Decathlon Europe, Maison Reciprocity, including a proposal for a 300+ unit mixed-use, mixed-income social housing community in Winston-Salem, NC.

large, their impact to the institution's context—rural Appalachia—was minimal. The program had historically gravitated to projects and research that helped local communities, evidenced by its earliest design/build endeavors; however, the Solar Decathlon projects did not become permanent artifacts of the region after the competitions nor of the campus itself.

IDEXlab: Integrating PBL, Curriculum, and Disciplines

In an effort to make PBL—specifically design/build—a more integral part of students' academic experience, the Building Science faculty sought to develop a program that intertwined with its existing programs of study. Supported by funding through a National Science Foundation (NSF) Transforming Undergraduate Education in STEM (TUES) grant, a new pilot program called the IDEXlab (Integrative Design Experience Laboratory) was created to mitigate the inherent curricular issues of past PBL efforts and develop a more interdisciplinary approach. Beginning in the summer of 2013, the faculty research team spent a year investigating comparable programs and planning the pilot curriculum. In the fall semester of 2014 and the spring semester of 2016, the IDEXlab (v1) pilot curriculum was executed as an alternative senior-year experience for sixteen students—eight from the Architectural Technology & Design concentration and eight from the Construction Management concentration. Each student replaced 18–20 hours of her or his senior level coursework within the major through the IDEXlab program.

The IDEXlab (Integrative Design Experience Laboratory) emerged, fundamentally, as an educational process that combines academic learning objectives with professional working experiences for students. A special course curriculum developed specifically for students who participate in IDEXlab ensures learning outcomes via a unique educational platform. As a "firm" comprised of AEC student "employees" and supported by faculty "principals," the IDEXlab offers design and construction services similar to those found in a professional office. To support this academic endeavor, the IDEXlab operates simultaneously in the design studio and in a high-bay construction lab that links the work of design intent and construction reality in a meaningful way.

During the yearlong experience, students were divided into a variety of interdisciplinary teams for the multiple projects within the curriculum. The first project was a ten-day design/build for electric composting toilet structures located on a farm operated by the university's Department of Sustainable Development. Although the two teams missed their deadlines and the final built products were of questionable quality, two buildings were designed and built with students learning many valuable lessons about budgets, time management, and team dynamics. Some shorter one-day charrettes were woven into the experience just before and during the process of the student teams' major projects. One eight-person team was charged to design and build a 5,600 gsf farmer's market in a nearby town while the other eight-person team was assigned a 1,100 gsf visitor's center for a local community park. Both projects were completed by the student teams: one on time and on budget; the other months late and well over budget.

With positive student learning success assessed during the pilot study, as well as the beneficial impact the projects provided to local non-profit and municipal clients, the IDEXlab was approved for a second year (v2) by program and department faculty. Due to the fatigue experienced by the ambitious efforts of the pilot—by faculty, students, and donors—IDEXlab v2 concentrated on developing an internal research project, the MOBILab.

The MOBILab—and its mobiLANDING counterpart (IDEXlab v4)—are products designed and built by the IDEXlab to benefit the work of students and faculty in the Department of Sustainable Technology and the Built Environment. The MOBILab (see Figure 4) is an

FIGURE 3. (left) Construction of IDEXlab's Alleghany County Farmer's Market. (right) Porch entry of IDEXlab's (v1) Valle Crucis Welcome Center.

energetically self-sustaining mobile classroom and research station that was created to meet the demand for classroom spaces at various remote research facilities used by the Department of Sustainable Technology and the Built Environment. These research sites provided no space to conduct classroom activities; the MOBILab addressed this deficiency with an indoor/outdoor classroom facility that includes student-designed tables and chairs, a presentation pin-up wall, and a large format wireless monitor for presentations and demonstrations. The MOBILab gives department faculty a flexible, deployable, PV-powered educational resource that assists instruction at disparate research sites, while giving the department itself a traveling billboard to the local community for the applied research occurring in its classrooms and labs.

While not an external client, this project still shared the goal of connecting students with the community and the opportunity for a shared mobile resource. The MOBILab cohort included twelve students selected from the Building Science program's three concentration areas (Architectural Technology and Design, Construction Management, and Sustainable Building Systems).

The scale of the MOBILab project offered a far more sustainable design/build model for both students and faculty in an immersive yearlong program. While the size restrictions for mobile structures is limiting, it provided clear constraints and boundaries for the students, letting them focus on a concentrated design problem. Additionally, the project allows students to consider design and detailing for all the primary components of construction. The MOBILab provides a prototype building and project type, which may be modeled for future IDEXlab projects.

IDEXlab v3 took on a different project type during the 2016–17 academic year. At the request of the College of Fine and Applied Arts, IDEXlab completed a major interior upfit and exterior renovation to an existing building in downtown Boone, NC. The resulting creative, collaborative, and coworking gallery, called HOW Space connects Appalachian students and the local community by showcasing creative work and hosting college and community events (see Figure 5).

The project focused heavily on interior millwork and programmatic flexibility, yielding little variety in design/build curricular content. HOW Space did, however, provide students

IDEXlab's (v2) MOBILab in use at the Sustainable Technology and the Built Environment's Small Wind and Research Demonstration Site on Beech Mountain.

relevant experience with the permitting process and getting more acquainted to interpreting code. Though this project presented a blurry line between what may be considered an "internal" or "external" project, HOW Space met relevant project selection criteria to be "a catalyst to the community." Our experience with this cohort of students confirmed what other authors have noted: if projects are meaningful to students, e.g., community based, students engage more fully in the project (Lee et al, 2014).

IDEXlab v4 completed two concurrent but widely disparate projects during the 2017–2018 academic year. The first project focused on the construction of a companion structure for the MOBILab called the mobiLANDING (see Figure 6). The mobiLANDING serves two primary programmatic functions. First, the mobiLANDING provides a permanent covered space to support activities for the Sustainable Technology and the Built Environment's Small Wind and Research Demonstration Site on Beech Mountain. A large sheltered deck keeps both people and equipment protected from the unpredictable weather patterns common to the area.

FIGURE 5. IDEXlab's (v3) HOW Space, a collaborative and creative collision space for the College of Fine and Applied Arts.

Second, the mobiLANDING gives the MOBILab a place to "dock" when it "visits" the Beech Mountain site. The mobiLANDING project had been designed and developed by a previous group of IDEXlab graduate students; due to permitting and procurement delays, the project was handed off to the 2017–18 undergraduate cohort for construction. The IDEXlab used the construction documents created by the graduate students to prefabricate the truss components and deck sections and then erected the structure on site. When paired together, the MOBILab and mobiLANDING create a multi-functional learning platform where theory discussed in the MOBILab classroom transitions to application during lab or workshop exercises on the mobiLANDING deck.

Simultaneously, the cohort developed a comprehensive master plan (see Figure 7) and schematic designs for the Covered Bridge Park and Edward's Island Park located in Elizabethton, TN. While the nature of this project is heavily design concentrated, it allowed students to explore and research the many layers and complexities of a community-based project in a downtown historic district. It also allowed students to work *with* a community, instead of *for* a community. The students engaged the community through meetings, visual preference surveys, and design presentations to receive community feedback. The students were enthusiastic to work on a design-driven project of this type, because they knew their work would make a positive impact for the community of Elizabethton. Although there was no directly related build component to the Elizabethton project, the mobiLANDING project provided a parallel and tangible experience to the curriculum.

STRENGTHS AND OPPORTUNITIES OF PBL

This portion of the paper synthesizes some of the insight our faculty have gained through the aforementioned projects. Each of these unique project endeavors extracted similar positive and negative outcomes as they relate to student learning. The most valuable points are identified here, as either a strength or an opportunity. These strengths and opportunities have been determined based on qualitative evaluation of the following metrics: the authors' observations over the course of 4 years of formal PBL implementation; student feedback through course evaluations and individual student reviews at multiple intervals throughout the academic year;

FIGURE 6. IDEXlab's (v4) mobiLANDING in use at the Sustainable Technology and the Built Environment's Small Wind and Research Demonstration Site on Beech Mountain.
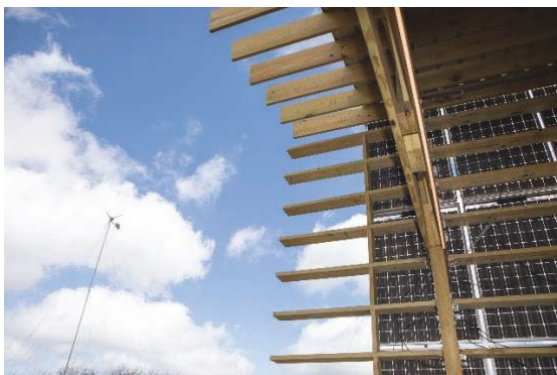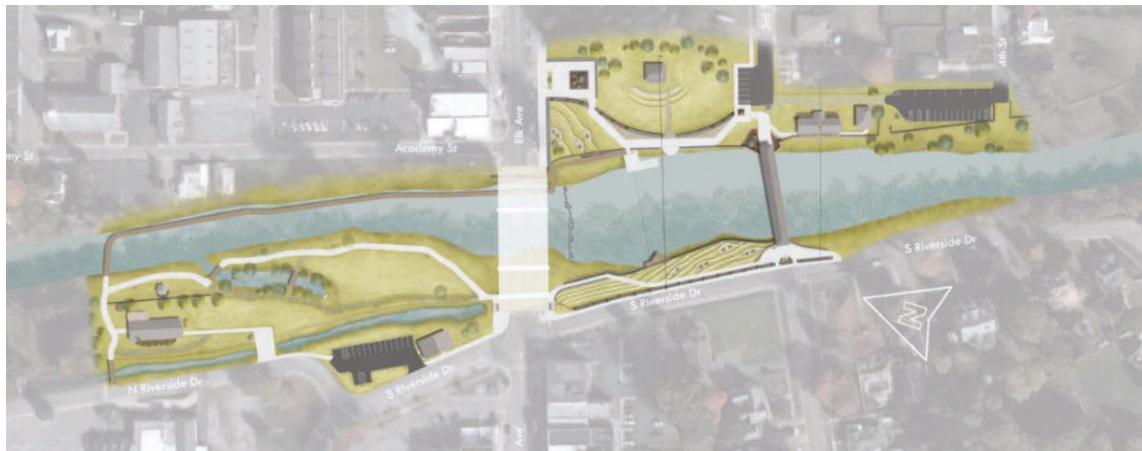
FIGURE 7. IDEXlab's (v4) master plan for Covered Bridge and Edward's Island Parks in Elizabethton, TN.

and industry professional's feedback after working with student alumni who participated in these projects.

Strengths

When students learn of the opportunity to work on a PBL project in lieu of traditional course equivalents, we typically find that those who are interested in the project are eager to work. Part of this eagerness, based on student feedback, is due to the mentality of "getting out of the classroom" or "having more freedom to work independently." Another critical factor that seems attract students is the opportunity to work on real projects for real clients. There is an additional motivational factor based on the type of project—refer to the next paragraph discussing community-based design problems and solutions for details. This intrinsic eagerness to work has obvious benefits. Students are self-motivated as they have the ability to engage in areas in which they are enthusiastic to concentrate. PBL students take pride in their work, which is partially due to their interest in being involved.

Additionally, students are more interested in involvement with community-based projects. When comparing student interest and performance between community projects versus corporate or institutional partners, it is apparent that the students are exceedingly more invested in the project when they can empathize with the project goal and are instrumental in making an impact in a community initiative. This is a critical component to project selection, as both the students and the client benefit.

A typical student learning outcome (SLO) or competence gained, based on feedback provided by future employers, are the soft skills realized intuitively by working on a team project. Students who undergo the PBL program are forced to exercise numerous soft skills throughout project phases, including but not limited to: communication; decision-making; self-motivation; leadership; time management; problem solving and creativity. Many of these skills are not easily achieved in a traditional classroom as the structure cannot provide for these various moments of interaction adequately or effectively. When students are participating in PBL, they are required to practice most if not all of these soft skills—internal and external to the team—in order to meet the needs of the project.

Operating in a similar manner as an office, PBL students are communicating with one another, clients, and industry partners, developing strong verbal skills and professionalism. They are making thoughtful decisions for the project to keep momentum, many of which require strong and creative problem solving skills. Time management is practiced through "class deliverables" and through accountability to the client. Many students are required, in some capacity, to take on a leadership role. Examples include: construction lead; design lead; energy engineering lead; structural design lead; procurer; estimator, etc. This allows specific students to have the primary responsibility of a designated project scope. Their peers rely on them to make the project successful, as many project roles impact other areas of the project. This requires team members to trust and motivate one another. Self-motivation might be the most complex learning outcome/practice to encourage and implement, as it seems to be a skill that is dependent on many personal variables.

While PBL seems to provide students exciting educational opportunities, it is still their own decision to be motivated. The majority of PBL students find avenues to be highly motivated in various capacities. PBL operates more as an office environment than a traditional classroom. The students have designated class time, Monday, Wednesday, and Fridays from 12:00 pm–05:00 pm, which is heavily utilized as self-directed work periods. Faculty are not typically lecturing during this course time, but rather make the rounds of the office/job site to support students on an as needed basis. Students tend to appreciate the opportunity to take their own initiative and have "job assignments." This self-directed office environment shapes students who appreciate education from a unique perspective, by creating a culture that expects students to be responsible for their own learning outcomes, with the support of faculty for direction and guidance.

Another positive outcome is the opportunity PBL provides to create an interdisciplinary experience. The majority of our students are either Building Science majors, with concentrations in Architectural Technology and Design, Construction Management, or Sustainable Building Systems, or Sustainable Technology majors. Other majors have been involved in various capacities, such as Interior Design, Industrial Design, Marketing, Business, Graphic Design, and Apparel Design.

PBL students may discover interests in areas they might not have explored in their designated discipline track. By having a project to explore diverse fields, students are allowed to glimpse into a wide array of career paths. This exploration finds some students unexpectedly learning what they want to do or, equally as significant, what they do not want to do.

Further, this interdisciplinary approach gives students a broader perspective. Where traditional courses segregate concentrations, providing narrow views, interdisciplinary courses entangle each concentration's mentality, decision-making process and reasoning. This creates professionals that are open minded and willing to learn from one another. It allows future designers to see into the mentality of future engineers or builders: why the schedule matters thus why the pace of design is urgent; why the design details impact the budget; and why the details impact the efficiency of installation. It allows future builders to see into the intent of future designers: why the design matters to the users; the value of carefully following construction drawings; and the importance and intention behind every design decision. It allows future engineers to see into the vision of future builders and designers: how the systems can be integrated into the design; and how the systems can influence design details. PBL allows students to practice one another's expertise, so that they may be better builders, designers, and engineers in the future through understanding and respecting one another's reasoning.

Interdisciplinary experiences develop more highly marketable students. They are able to enter the industry with a larger array of skill sets, in assorted industry fields. This affords them the opportunity to change fields easily in the event of a change of interest or change in the market. PBL students tend to be unique employees that employers seek, as they are both proficient and versatile. Other authors have also discussed how PBL improves student learning and prepares graduates for professional practice including such benefits as: teamwork skills; increased student motivation; articulation between theory and practice; and problem solving (Fernandes, 2014).

Not only are the students more marketable, but these students are pursuing job opportunities which fulfill their passion for sustainability in the industry. Through the PBL experiences, students adopt a sustainable perspective through the design and construction process. Students have independently pursued niche fascinations integrating responsible environmental considerations through various projects opportunities. Examples include; architecture students narrowing in on the significance and impact of daylighting and orientation, construction management students considering and coordinating for standard material sizes to reduce waste, sustainable building system student's energy modeling various iterations to find the optimal solution, and even students with landscape interest pursuing opportunities for rain collection and green roofs. Each of these sustainable interests require more work from the students, to understand, to research, and to model alternative solutions, yet, the students seem more eager to do this extra work. These independent pursuits for environmental considerations could be attributed to their eagerness and passion to provide the best solution for their client while also feeling a sense of accomplishment in making informed environmentally conscious decisions. As sustainability is the foundation to the Building Science curriculum at Appalachian State University, students are motivated to implement these core classroom concepts on PBL projects. The students are eager because they have determined reasoning to support their decision making, improving the project outcome while considering the environment. This curricular experience leads students to careers which prioritize a smarter energy future.

Opportunities

Much like an office, PBL classrooms require a unique form of evaluation, one which is primarily and prominently qualitative. This transition for students, from quantitative to qualitative feedback, can be difficult to accept and fathom, as students are eager to see a grade with each assignment. With project-based learning, each student has many individual and group "assignments" with various deadlines. This presents one of the most complex pedagogical and curricular aspects of PBL. How do instructors fairly evaluate and provide an appropriate amount of feedback? For each cohort, grading is tweaked to complement the project; however, most often PBL students have been graded individually based on performance towards major project milestones. Typically, students meet with the faculty at multiple points in the year to discuss their individual performance and have an opportunity to ask questions and give their feedback.

Additionally, students track their work weekly in the form of a timesheet and a weekly reflection. The timesheets are ways for the students to visually realize their hours and for instructors to understand how many hours were used and how those hours were utilized. In the weekly reflections, students are given the opportunity to reflect, provide insight and, in some cases, vent on the week's successes and difficulties.

How might qualitative data be evaluated to confirm all learning objectives are being achieved? Our efforts have not yet implemented an established method to integrate measurable

metrics for learning outcomes. While students are certainly learning through unique experiences and gaining necessary professional soft skills, it is still to be determined if PBL students are achieving the same learning outcomes as required in a traditional course track. In the coming spring semester of 2019, student's depth of knowledge in traditional construction project planning and scheduling methods and techniques will be compared through oral examination of a sample of both "traditional" and PBL students. More details about this comparison are provided in the following section on IDEX EXCEL.

Is PBL feasible and sustainable for both faculty and students? PBL has proved to be a challenging workload for many students with the demanding time and energy required to make the project successful. Many students struggle to find a balance and compete with other responsibilities such as traditional coursework, extracurriculars, part-time jobs, etc. By the end of major deadlines and semesters, the students are drained. Fernandes, 2014 also noted that some students complain that PBL creates too large a workload (as compared to traditional teaching). Additionally, this same time and energy requirement directly impacts faculty. The preparation and implementation of project-based learning requires extensive time and commitment, and when paired with a regular course load, is not sustainable for faculty to maintain. This workload issue must be solved through proper project scope creation that allows for reasonable work and completion during the academic cycle.

One other potential solution to keep students from being overwhelmed, is to provide them with a smaller problem based learning (smaller in scale and scope relative to project-based learning) opportunity earlier in their academic careers. This could prevent the initial feeling of being overwhelmed by an open-ended design problem and allow students to be more effective earlier in the time frame of the larger PBL capstone experience. Using problem based learning early in the process as a support for future, larger scale project-based learning was suggested by (Chinowsky et al, 2006), where problems are considered to be much smaller, more focused, and more trackable design exercises than projects.

Maintaining support for the resources necessary for PBL is an ongoing effort. These projects require various resources including; a high bay building with office and meeting spaces, tools, model-making materials, building materials, computers and specialized software programs, funding for research and exploration, truck(s) and trailers. The original pilot, funded by the National Science Foundation. While some of these resources are supported by the client, the operational costs are difficult to bear without additional sponsors, Departmental and College support.

PRACTICAL APPLICATION OF PBL IN DESIGN AND CONSTRUCTION EDUCATION

Is PBL a useful teaching tool in design and construction education? PBL should be well suited to improving overall student learning outcomes for design and construction students since PBL has been shown to improve student learning/retention and prepare graduates for professional practice including such benefits as: teamwork skills, increased student motivation, articulation between theory and practice, and problem solving. Design and construction is an applied profession and, as such, students should be exposed to projects involving real buildings.

What are the problems affecting practical application of PBL into an undergraduate design and construction curriculum?

It is a problem of motivation. The challenge must offer a meaningful problem best represented by a real client. Developing a cache of contacts and potential projects early in the process is imperative so that an appropriate project is always ready for the incoming student cohort. Suggestions include working with local communities and organizations such as Habitat for Humanity. Another motivational scheme to consider is more extensive use of modern media tools. A key aspect of modern media is that communications are two-way and often occur in real-time. Current/traditional teaching methods, even those that use online platforms such as Moodle and Blackboard, tend to be passive for students with one-way communication from the professor to the student or from the textbook to the student—this two-way interactive communication can be developed in Wiki's and other tools as suggested by Chu et al, 2017.

It is a problem of students feeling overwhelmed. Starting with problem based learning instead of project based learning seems a promising springboard for preparing students adequately. Smaller problem based learning experiences early in the curriculum such as building energy audits or assessments of moisture problems in existing structures provide an appropriate scale and scope of work for students, reserving larger project based learning experiences are for final year capstones. However, the potential exists to allow younger students to participate in limited roles in the final year capstone—allowing seniors to expand their management role and giving younger students another opportunity to become familiar with PBL in a less demanding capacity. The same co-teaching opportunity exists if the department has a graduate program. Graduate students can coach final year students as well.

It is a problem of assessment. Frequent opportunities for formative self-assessment and revision are paramount to a successful PBL experience. Instructors should provide opportunities for detailed discussion of student progress and performance and give the opportunity for students to give feedback on both the problem and the instructor's performance; however, such detailed discussions are too time consuming to carry out on a frequent basis (perhaps only a midterm discussion and final wrap-up are possible). In order to give more frequent opportunities for assessment, self-assessments and joint-peer assessments can be implemented. The self-assessment can take the form of a weekly reflective writing exercise.

Many of the methods and solutions suggested above were also suggested by Barron et al, 1998 who proposed the following four curricular design principles: must set learning-appropriate goals; must have scaffolds that support both student and teacher learning (such as using problem based learning first as an introduction to PBL); must have frequent opportunities for formative self-assessment and revision; and create both external and internal social organizations that promote participation and result in a sense of agency (such as setting up student teams properly and having an appropriate "client" that will get students motivated).

CONTINUING REFINEMENT OF PROJECT BASED LEARNING ACTIVITIES

After acknowledging and examining areas strengths and opportunities through past experiences with PBL, the authors developed a list of objectives to refine the PBL methodology. These objectives and goals were used to propose a pilot restructuring of the PBL program.

Opportunities to objectives

1. Organization: Some students find the transition from a traditional classroom to a project based learning experience difficult due to the organic nature of PBL compared to the structured and organized learning in the traditional classroom. *Creating a framework to*

allow for a structured project based learning experience should be considered, merging the organized and focused delivery of content of a traditional classroom with the ideal experience of PBL.

2. Management: Students have competing demands for their time due to other rigorous classes in advanced coursework curriculum. Many students find they are overwhelmed by managing the intense workload required of PBL while simultaneously being enrolled in upper level coursework. *Restructuring the IDEXlab curriculum to allow for focused PBL work, isolated from traditional curriculum, will provide students an opportunity to excel in their traditional coursework and in PBL experience.*

3. Focused Learning: If core content courses are substituted by PBL equivalents, all students do not get the same learning experience due to team specialization. For example, only one or two students may get detailed scheduling experience during the PBL experience, while others may not be integrated into that portion of the project. *Determining a way to provide each student the same core content courses while still allowing them the PBL experience is critical to provide the required curriculum to every student.*

4. Involvement: Bringing in experts in the industry has been a highlight for many students. *Continuing to involve industry professionals across each discipline provides an interdisciplinary learning experience for all students.*

5. Interdisciplinary: Only a limited number of students are able to participate in large end-of-year PBL projects through the IDEXlab program. *Providing an opportunity to allow more students outside of the IDEXlab framework the opportunity to be involved with IDEXlab projects in some capacity was seen as another opportunity for improvement. Please refer to the section on curriculum changes below for further discussion.*

IDEXLAB EXCEL PROPOSED PILOT PROGRAM

IDEXlab will implement a modified program, IDEXlab EXCEL, during the 2018–2019 academic year, funded by Appalachian State University's College of Fine and Applied Arts (FAA) through an approved Innovative Interdisciplinary Curriculum Proposal. IDEXlab EXCEL will be restructured in five specific ways in order to rethink areas of opportunity and meet the objectives listed above.

1. Organization: Classes are structured individually as three-week workshops, allowing for five three-week classes over the course of fifteen weeks, creating IDEX EXCELerated: a semester-long program of IDEXlab intensives.

2. Management: This concentrated course format with help reduce competing "distractions" and help students find focus in their curriculum.

3. Focused Learning: Allowing courses to be given one at a time permits focused examination of a discipline-specific topic area, thus affording opportunities for better comprehension, retention and application. This will coordinate with the proposed curriculum changes addressed below.

4. Involvement: Each three-week course will host a one-week long IDEXlab workshop facilitated by a paid building industry expert.

5. Interdisciplinarity: These workshops would be open to all majors in the department and coordinated with the course-substituted section. This offers a feasible, flexible and engaging path toward integrating interdisciplinary learning activities in the classroom(s).

This restructuring to the program is an active response to the areas deemed important to improve. After this IDEXlab EXCEL program is piloted, an analysis will be conducted to determine the strengths and areas of opportunity for this methodology. In addition to this proposed pilot program, incorporating critical curricular changes discussed below are necessary to facilitate the impact of these changes. Together, the traditional program paired with the pilot program are intended to be a new baseline for improvement. Parallel to these changes in the IDEXlab, the Building Science program curriculum is undergoing a similar restructuring process.

CURRICULUM CHANGES

Emerging from relatively humble origins within an Industrial Arts program, Building Science at Appalachian State has developed into a comprehensive degree program offering three distinct concentration areas to over 400 student majors (as of 2017–18) in both four-year and 2+2 transfer program tracks. For all its activities and successes over its twenty-plus year history, the evolution of the program(s) of study has notably lacked any systematic planning or methodological framework. Instead, the program faculty focused on practical, hands-on and applied learning responsive to industry trends and professional feedback. Eschewing a siloed approach to building industry education, the faculty have developed the Building Science program to value equally the roles of design, engineering and construction in order to create performative structures that enhance the built environment. This pedagogical mentality laid the groundwork for the types of PBL endeavors discussed throughout this paper. In turn, the experience gained through PBL activities have afforded the Building Science faculty an opportunity to holistically revision and restructure the curriculum for the first time since its inception.
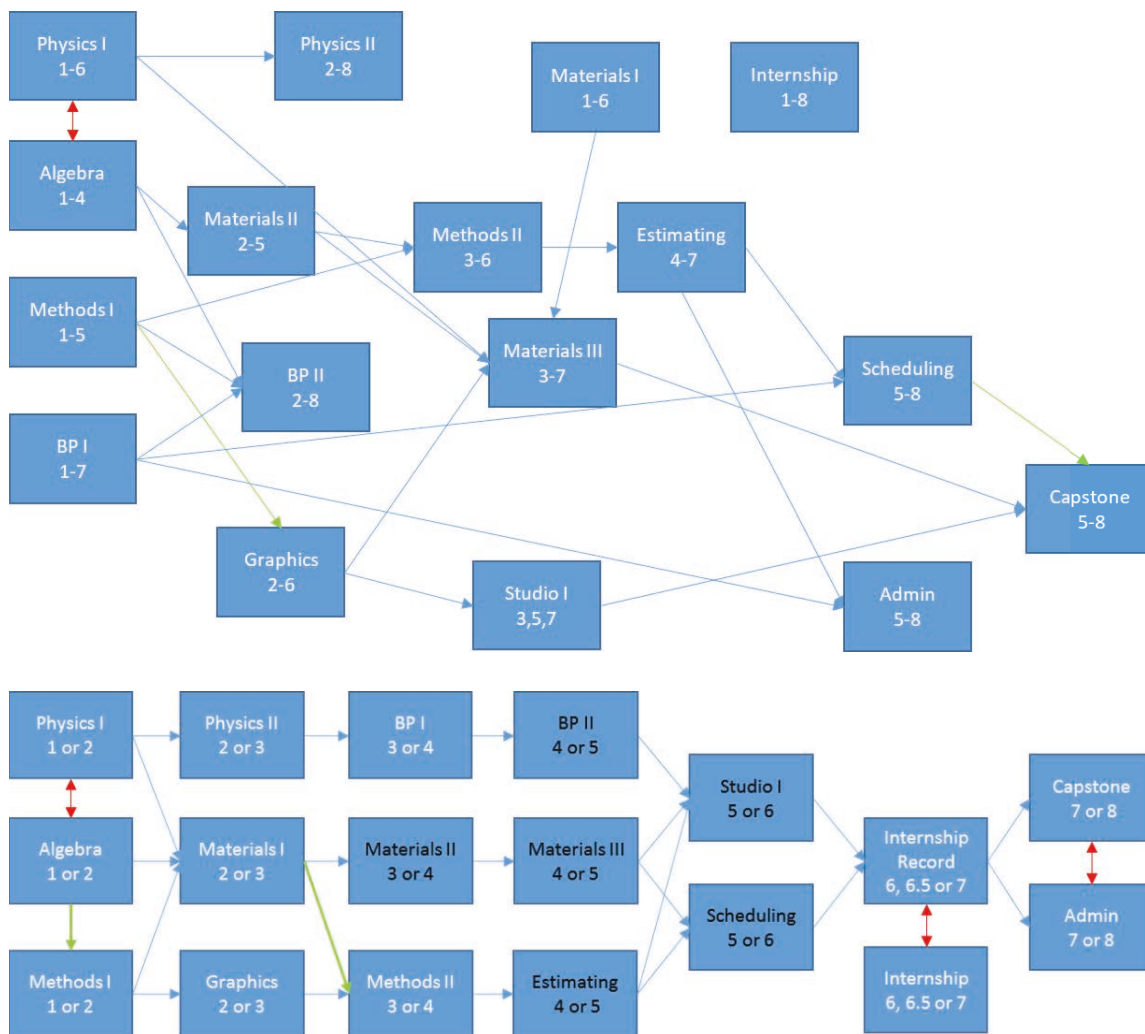
The three-year Building Science curriculum revisioning process, from 2016 to 2019, began with a thorough assessment and review of one fundamental question: Should the Building Science program pursue accreditation?

A faculty task force with representation from architectural, engineering and construction management disciplines evaluated this question by surveying administrators, alumni, faculty, professionals and students while simultaneously reviewing different types of accreditation standards and similar undergraduate programs across the country. Unsurprisingly, the task force discovered few program parallels and limited accreditation standards to align with the uniquely aggregated curriculum profile. More surprising, perhaps, was the overwhelming indifference among colleagues, industry professionals and students regarding program accreditation. Citing the inherent interdisciplinarity and flexibility within the current program of study structure as its key strength, the task force recommended that the Building Science program align closely to a specific accreditation standard without pursuing accreditation directly. A new Building Science program plan was subsequently developed, outlining targeted program goals and strategic learning objectives (SLOs) modeled on the ABET accreditation standard for an Applied Science program. These new goals and outcomes completed the first of three stages in the curriculum revisioning process, creating a comprehensive framework to structure, measure and assess three primary student proficiency areas: analytical/technical; synthetic; and professional.

The second stage, completed during the 2017–18 academic year, expanded the scope of work to include the full Building Science faculty. The faculty divided into teams based on discipline expertise and reviewed all courses offered for each program of study. Seeking overlaps and gaps relative to objectives, content and assessment methods, the faculty identified strengths, weaknesses and opportunities in the existing curricular structure. A package of curriculum

changes was developed to rebrand, resequence and revise existing courses. Included in these proposals were significant revisions to course prerequisites and corequisites. By narrowing the field of prerequisites for each course to capture only its immediate predecessor course(s), a more linear path through the program of study was established. This type of curricular "housekeeping" has shifted the Building Science program toward a cohort model, a move that benefits the program in a multitude of ways. A chapter-by-chapter approach to the curriculum affords greater clarity for students and faculty alike. Curricular redundancy—a necessity of the earlier non-sequential model—has been removed, allowing for deeper course content development at the 3000 and 4000 (junior and senior) levels. Further, a sequence for applied problem based and project based learning has been embedded into the new program of study "flows" for each concentration area. PBL courses operated through the IDEXlab—which increasingly acts as an experimental pedagogical and curricular incubator—are categorized as special topics courses that parallel the content and assessment criteria in established major courses.

FIGURE 8. Building Science 577C (Construction Management) program of study course flow before and after second stage curriculum revisioning.

During the third stage of this curriculum revisioning process (2018–19), the Building Science faculty will finalize a package of proposals that formalize additional and needed courses focused on building performance and integrated project delivery (IPD) via advanced BIM platforms, while mapping SLOs and assessment metrics from the 2016–17 program plan to specific program courses in careful accordance with university Institutional Research, Assessment and Planning (IRAP) guidelines. Courses in the Building Science program now present clear sequences organized by content modules and concentration areas including: Materials (1–3); Methods (1–3); Architectural Design Studio (1–4); Building Performance (1–4); and Construction Management (1–4). All students in the undergraduate program must complete an interdisciplinary CORE of courses during semesters 1–4 to prepare them for discipline specific courses in their respective concentrations during semesters 5–8. In preparation for vertically scheduled PBL courses in semesters 7–8, students are required to engage in a professional internship during the summer between their junior and senior year. By gaining professional experience and OSHA 30-hour safety certification in their respective disciplines, students return to campus better prepared for the challenges of integrated PBL activities in both traditional classroom settings and programs like the IDEXlab. With twelve to eighteen semester hours allotted for major elective credits, students are further encouraged to pursue minors in other academic fields useful to building industry professionals, such as: Business; Community and Regional Planning; Spanish; or Sustainable Technology. These curricular restructuring efforts, when viewed as a whole, have allowed the Building Science faculty to clarify and tighten the curriculum without losing the comprehensively interdisciplinary ethos that makes the program—and its PBL activities—unique in undergraduate design and construction education.

CONCLUSION

The implementation and practice of PBL in an undergraduate design and construction program at Appalachian State University has provided many strengths, has posed many opportunities and represents an ongoing endeavor. Our program faculty are committed to further exploration of PBL delivery, retention and assessment. As we continue this always evolving curricular journey, we will seek to confirm the seeming benefits in student learning outcomes, find ways to scope/scale the projects to avoid overworked students and faculty and develop innovative strategies to allow all students in the program to be engaged in a thoughtful and extensive project based learning experience before they graduate and move into the workforce.

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